Temperature Dependent Carrier Dynamics in GaInN/GaN Multiple Quantum Wells with Varying In Composition

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GaInN quantum wells (QWs) are commonly used in UV-blue laser diodes and commercially available nitride based LEDs. To study the carrier recombination process in GaInN QWs is of great interest in order to improve the performance of those light emitting devices. A widely discussed recombination model for this material proposes that spatially localized carriers at below band gap centers are responsible for efficient luminescence [1,2] in the presence of a high density of defects. To develop a better understanding of how growth conditions affect carrier localization and thus luminescence properties in GaInN QWs, in this work we have carried out a systematic study of emission for LED samples with varying In composition (x=0.08-0.34) by measuring the temperature and emission energy dependent photoluminescence (PL) decay.

The samples used in the present study were LED structures grown on c-plane sapphire by metalorganic vapor phase epitaxy (MOVPE), which have 5QWs with $Ga_{1-x}In_xN$ (2nm) wells and GaN:Si (7.5nm) barriers. Three samples with different In compositions of x=0.08, x=0.26 and x=0.34 were prepared. To make this study consistent for three different samples, only the In composition of the QWs was changed and the rest of the growth parameters were nominally identical. These LEDs show electroluminescence peaks at 410nm, 445nm and 475nm respectively at an injected current density of 20A/cm^2.

Fig.1 shows PL decay time as a function of emission energy at room temperature for three samples. For higher In composition, x=0.34, strong carrier localization like characteristics, faster decay at higher emission energy and slower decay at lower emission energy side, were observed. Fig.2 shows temperature dependent (7K-300K) PL decay time taken across the entire emission energy for three samples. Similar trends in decay time changes with temperature were measured. Differences observed in temperature induced changes of the decay time are most likely due to the differences in localization properties of the three samples since the temperature dependence of piezoelectric field is probably a less significant effect. These decay time changes with temperature can be divided into three temperature regions (I, II, III) as depicted in Fig.2. In the case of x=0.08, as the temperature is raised (7K-90K) the difference between low and high energy decay time increases (I). In the next region (90K-240K) this difference begins to decrease (II) probably due to an increase in nonradiative recombination and delocalization of carriers by thermal energy. Finally (240K-300K), the decay time across the entire PL spectrum decreases rapidly (III) and is dominated by the increase of nonradiative recombination rate. For higher In composition LEDs, however, only I and II regions were observed and the characteristic temperature at the boundary between regions I and II increases with increasing In composition. For the sample with x=0.34 the difference in low and high energy decay time is large even at room temperature, which indicates strong carrier localization. These results suggest that carrier recombination through localized states where the localization depth increases with increasing In composition in the MQWs are dominant in the luminescence processes for this series of samples.

Acknowledgements

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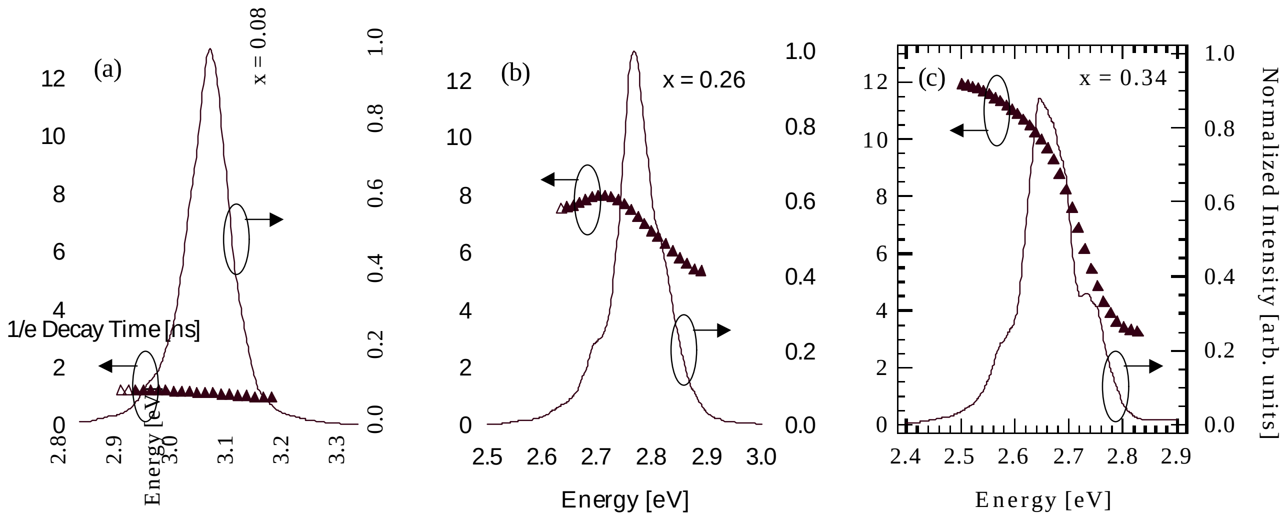

Fig.1 Photoluminescence decay time as function of emission energy at room temperature for GaInN/GaN-MQW LEDs with (a) x=0.08, (b) x=0.26 and (c) x=0.34.

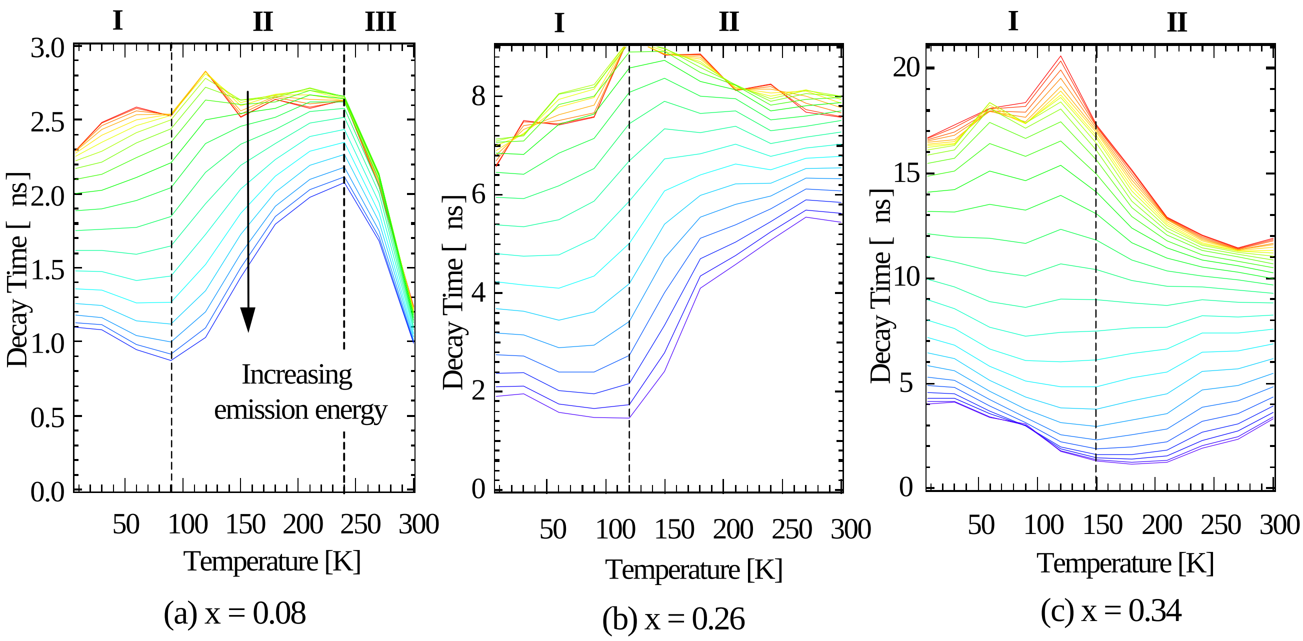

Fig.2 Temperature dependence of photoluminescence decay time measured across the entire emission spectrum for GaInN/GaN-MQW LEDs with (a) x=0.08, (b) x=0.26 and (c) x=0.34.